COE CST Fourth Annual Technical Meeting

Robust and Low-Cost LED Absorption Sensor for Simultaneous, Time-Resolved Measurements of CO and CO_2

Dr. Subith Vasu (PI)
Dr. Jayanta Kapat (Co-PI)
Dr. Bill Partridge Jr. (Collaborator)
Kyle Thurmond (Graduate Student)
Zachary Loparo (UG Student)

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Center of Excellence for Commercial Space Transportation

Agenda

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- Task Description
- Schedule
- Goals
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- Conclusions and Future Work

Team Members

Principal Investigators

Dr. Subith Vasu
University of Central Florida

Dr. Jay Kapat (Co-PI)
University of Central Florida

Students

Kyle Thurmond
University of Central Florida

Zachary Loparo
University of Central Florida

Collaborator

Dr. Bill Partridge Jr.
Oak Ridge National Laboratory

Organizations

- Center for Advanced Turbomachinery and Energy Research (CATER), University of Central Florida
- Fuels, Engines, and Emissions Research Center, Oak Ridge National Laboratory

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Task Description

Relevance to Commercial Space Industry

- CO/CO_2 measurements are relevant to the health and safety of the crew.
- In addition to being toxic, time-resolve measurements of CO could be used to detect fuming which may lead to fire or explosion.

Statement of Work (Project starterd: September 2014)

- Bench scale development and testing. Sensor sensitivity (minimum detection limit), time-response, and stability.
- Develop quantitative spectroscopic models that can be used to accurately derive concentration information based on absorption.
- Models for heat transfer will be developed and utilized to minimize radiation effects that could impair the sensor to function properly. Such models will be implemented in commercially available software (e.g., ANSYS)
- Sensor design and housing design must be optimized for spacecraft environment. This would require a caged design that will house every component keeping the weight to the allowable values. We will use Zemax software to arrive at the best design which will maximize sensor sensitivity.

Schedule

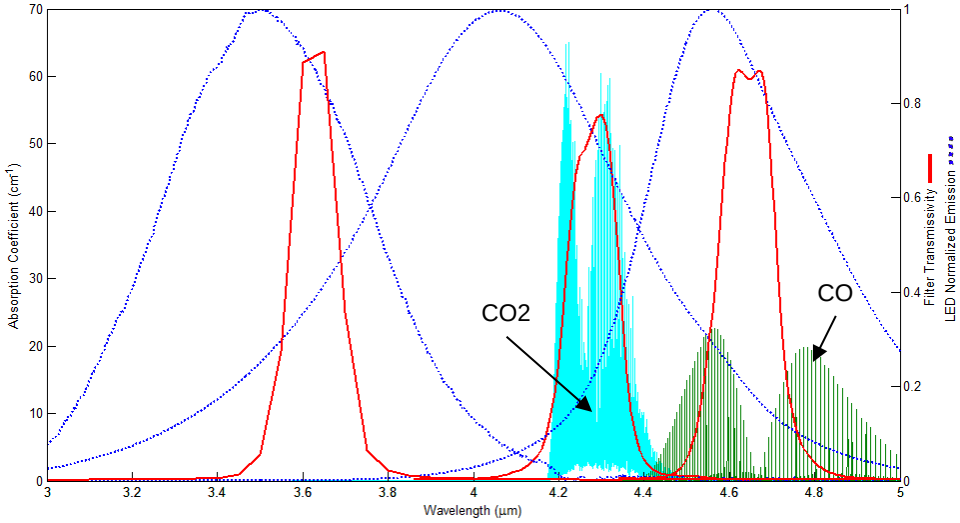
- Bench scale development and testing. Sensitivity, time-response, and stability.
  - Complete
- Develop quantitative spectroscopic models that can be used to accurately derive concentration information based on absorption.
  - January 2015
- Sensor and housing design must be optimized for spacecraft environment. We will use Zemax software to arrive at the best optical design which will maximize sensor sensitivity and minimizes overall size
  - March 2015.
- Models for heat transfer will be developed and utilized using commercially available software (e.g., ANSYS) to minimize radiation effects that could impair the sensor to function properly
  - April 2015
- To reduce the likeliness of failure during high altitude balloon, the system will be operated and evaluated using a laboratory environmental chamber which can simulate these conditions.
  - August 2015
- High altitude balloon testing.
  - Fall 2015

Sensor Design

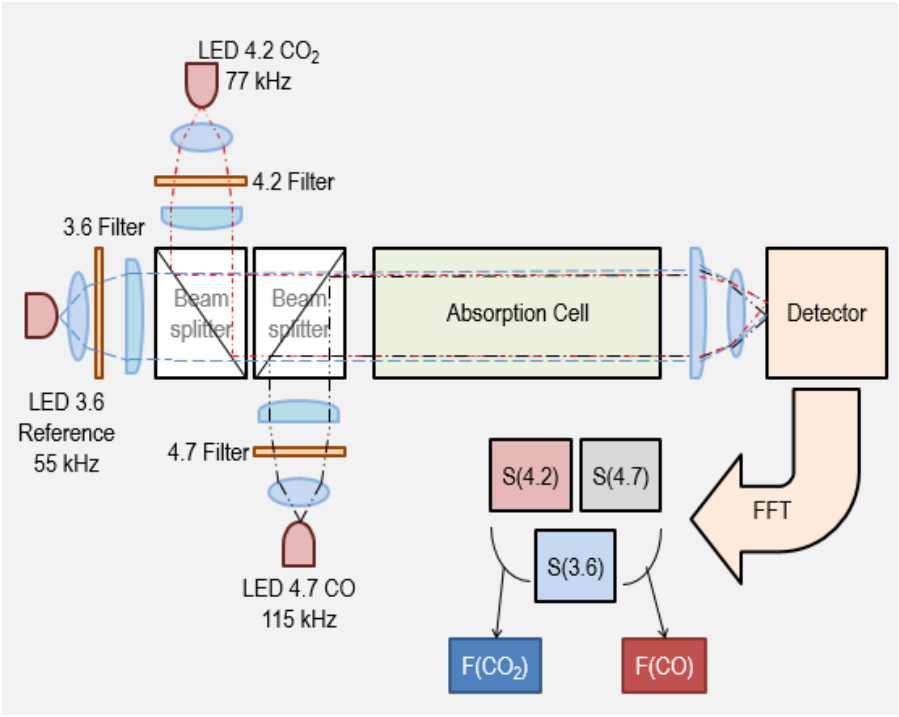
- Three MIR LEDs centered at
  - 3.6μm (for reference)
  - 4.2μm (CO_2)
  - 4.7μm (CO)
- Band pass filters

- Collimating lenses
- Pellicle beam splitters
- Thermo-electrically cooled photovoltaic detector

LED and Filter Spectral Profiles Overlapping Absorption Features of CO_2 and CO

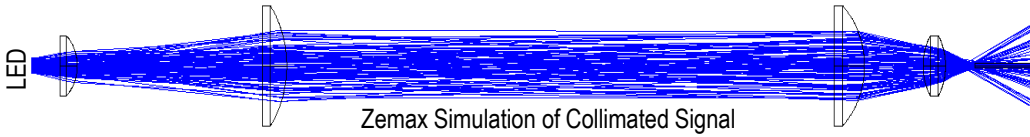


Simple Schematic of Sensor System



Goals

- Maximize sensitivity and reduce noise by optimization of optics and electronics.

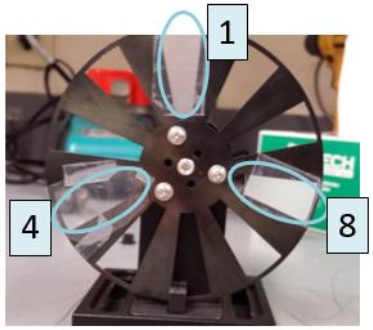


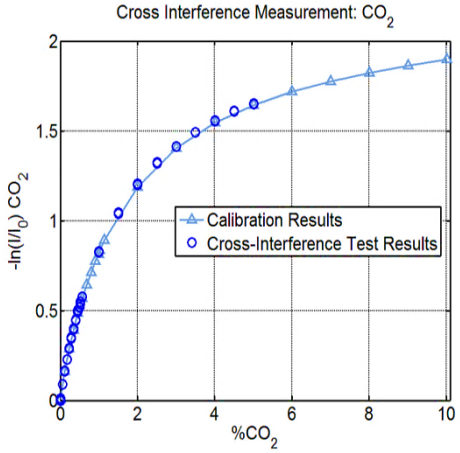
Zemax Simulation of Collimated Signal

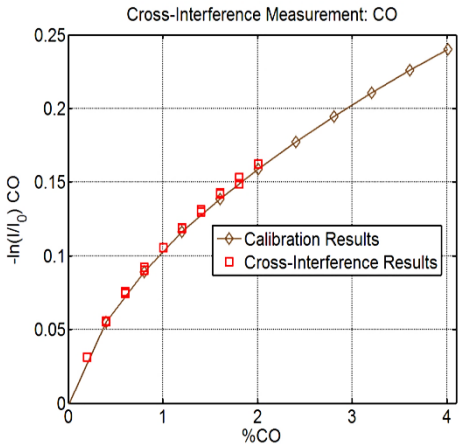
- Explore models for broad-spectrum absorption for greater flexibility in design.
- Adapt sensor and housing design for spacecraft environment.
- Validate optimization and ruggedized design:
  - Species interference study
  - Simulated conditions in environmental chamber
  - Balloon testing in high altitude, microgravity environment

Results

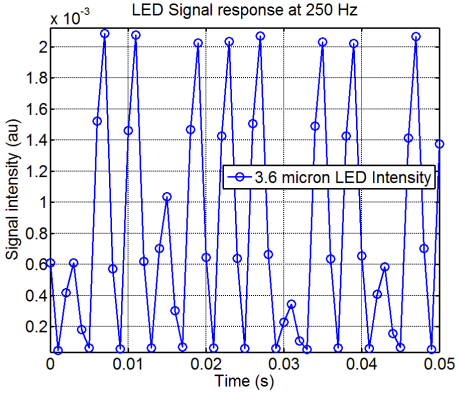
- Early evaluation testing done at ORNL
- Measurements were taken using a flow cell with a path length of 8cm
  - Neat CO_2 measurements
  - Neat CO measurements
  - Simultaneous measurements/evaluation of cross-interference
- Time resolution testing
  - Chopper wheel with plastic to simulate absorption



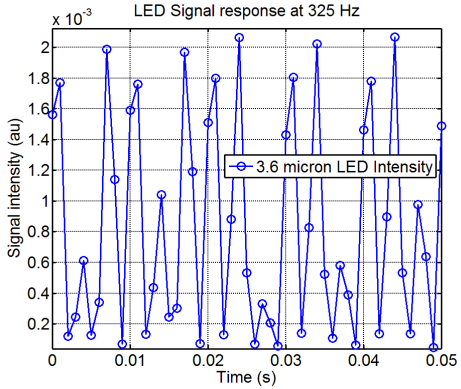




No Cross Interference between CO_2 and CO



Response at 250Hz
No aliasing observed



Response at 325Hz
Signal not fully resolved

Related Publications

- 2013 Eastern States Section of the Combustion Institute Fall Technical Meeting – Presentation
  - Development of a LED-based sensor for simultaneous, time-resolved measurements of CO and CO_2 from combustion exhausts
- 35th International Symposium on Combustion – Work In Progress Poster
  - Design and Validation of LED-Based Absorption Sensor for Simultaneous Detection of CO & CO_2

Conclusions and Future Work

Measurements of CO/CO_2 will be highly valued for determining air quality effecting crew health and detecting fires.

Future Work

- Developing current sensor design for spacecraft environment and requirements.
- Construction of caged sensor system.
- Validating spacecraft ready sensor design using environmental chamber and high altitude balloon.
- Improve performance and possibly extend to measuring other species (e.g., N_2O oxidizer leak).